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BIG PINE G-E-M RESOURCES AREA (GRA NO. CA-08) TECHNICAL REPORT (WSAs CA 010-059 and 010-063)

Contract YA-553-RFP2-1054

Prepared By

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For

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Final Report

April 22, 1983

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EXECUTIVE SUMMARY

The Big Pine Geology-Energy-Minerals (G-E-M) Resources Area (GRA) lies along the east front of the Sierra Nevada, extending about fifteen miles north and south from the town of Big Pine, Inyo County, California. There are two Wilderness Study Areas (WSAs) in it: WSAs CA 010-059 and 010-063.

In the northern half of the GRA granitic rocks about 100 million years old predominate, with some small masses of metamorphosed sediments that are 300 to 600 million years old. In the southern half of the GRA the same rocks are present, but for the most part are covered by either volcanic rocks or gravel valley fill, both of which are less than a couple of million years old.

There are no major mining districts in the GRA, although scattered small mines have produced tungsten (a critical mineral), and some feldspar has been produced, as well as rather large quantities of perlite. There are no patented claims in the GRA but there is a scattering of unpatented claims.

The southern segment of WSA CA 010-059 is classified as having low favorability for both metallic and nonmetallic mineral resources with very low and low levels of confidence, respectively. The northern segment is classified as having low favorability for tungsten, a strategic and critical mineral, with moderate confidence on the basis of geology projected into the area from surrounding outcrops. The northeast corner of the northern segment, which has numerous unpatented claims, is classified as having low favorability for volcanic cinders with a high level of confidence; all of Red Mountain is composed of cinders. Both segments of the WSA have low favorability for uranium and thorium with low confidence, and moderate favorability for geothermal resources with moderate confidence. There is very low favorability for oil and gas, coal, oil shale, tar sands, and sodium and potassium.

Most of WSA CA 010-063 is classified as having very low favorability for both metallic and nonmetallic minerals with low to moderate confidence. The middle segment, near Keough's Hot Spring, has moderate favorability for tungsten with moderate confidence, on the basis of known prospects and favorable geology. A narrow strip of the southernmost segment is classified as highly favorable for nonmetallic minerals, with a high level of confidence -- feldspar has been mined from a dike that traverses almost the entire segment. The remainder of the WSA has low favorability for nonmetallic minerals, with low confidence. The entire WSA has low favorability for uranium and thorium, with a low level of confidence. The middle segment has high favorability for geothermal resources, with a high level of confidence -- Keough's Hot Spring has used geothermal waters in a resort for many years. The remainder of the WSA has moderate favorability for geothermal resources, with a moderate level of confidence,

because of its geological environment. There is very low favorability for oil and gas, coal, tar sands, oil shale, and for sodium and potassium.

Field examination of a few prospects is recommended.

I. INTRODUCTION

The Big Pine G-E-M Resources Area (GRA No. CA-08) covers approximately 116,000 acres (467 sq km) and includes the following Wilderness Study Areas (WSAs):

WSA Name	WSA Number
Tinemaha	010-059
Coyote Southeast	010-063

The GRA is located in California in the Bureau of Land Management's (BLM) Bishop Resource Area, Bakersfield district. Figure 1 is an index map showing the location of the GRA and Figure 2 outlines the boundaries of the GRA and the WSAs on a topographic base at a scale of 1:250,000. The area encompassed by the GRA is near 37°00' north latitude, 118°20' west longitude and the GRA includes the following townships:

T 7 S, R 32,33 E	T 10 S, R 33,34 E
T 8 S, R 32,33 E	T 11 S, R 33,34 E
T 9 S, R 33,34 E	

The areas of the WSAs are on the following U. S. Geological Survey topographic maps:

15-minute:

Big Pine	Mt. Pinchot
Bishop	

The nearest town is Big Pine which is centrally located on the eastern GRA boundary on U.S. Highway 395. Access to the area is via U.S. Highway 395 between Bishop and Independence. Access within the area is along east-west unimproved roads across the alluvium at the base of the Sierras. Such roads include Freeman Creek, Shannon Canyon, Big Pine Creek, Burch Creek, Red Mountain Creek and Division Creek roads.

Figure 2 outlines the boundaries of the GRA and the WSAs on a topographic base at a scale of 1:250,000.

Figure 3 is a geologic map of the GRA and vicinity, also at 1:250,000. At the end of the report, following the Land Classification Maps, is a geologic time scale showing the various geologic eras, periods and epochs by name as they are used in the text, with the corresponding age in years. This is so that the

reader who is not familiar with geologic time subdivisions will have a comprehensive reference for the geochronology of events.

This GRA Report is one of fifty-five reports on the Geology-Energy-Minerals potential of Wilderness Study Areas in the Basin and Range Province, prepared for the Bureau of Land Management by the Great Basin GEM Joint Venture.

The principals of the Venture are Arthur Baker III, G. Martin Booth III, and Dennis P. Bryan. The study is principally a literature search supplemented by information provided by claim owners, other individuals with knowledge of some areas, and both specific and general experience of the authors. Brief field verification work was conducted on approximately 25 percent of the WSAs covered by the study.

None of the WSAs in this GRA were field checked.

One original copy of background data specifically applicable to this GEM Resource Area Report has been provided to the BLM as the GRA File. In the GRA File are items such as letters from or notes on telephone conversations with claim owners in the GRA or the WSA, plots of areas of Land Classification for Mineral Resources on maps at larger scale than those that accompany this report if such were made, original compilations of mining claim distribution, any copies of journal articles or other documents that were acquired during the research, and other notes as are deemed applicable by the authors.

As part of the contract that resulted in this report, a background document was also written: Geological Environments of Energy and Mineral Resources. A copy of this document is included in the GRA File to this GRA report. There are some geological environments that are known to be favorable for certain kinds of mineral deposits, while other environments are known to be much less favorable. In many instances conclusions as to the favorability of areas for the accumulation of mineral resources, drawn in these GRA Reports, have been influenced by the geology of the areas, regardless of whether occurrences of valuable minerals are known to be present. This document is provided to give the reader some understanding of at least the most important aspects of geological environments that were in the minds of the authors when they wrote these reports.

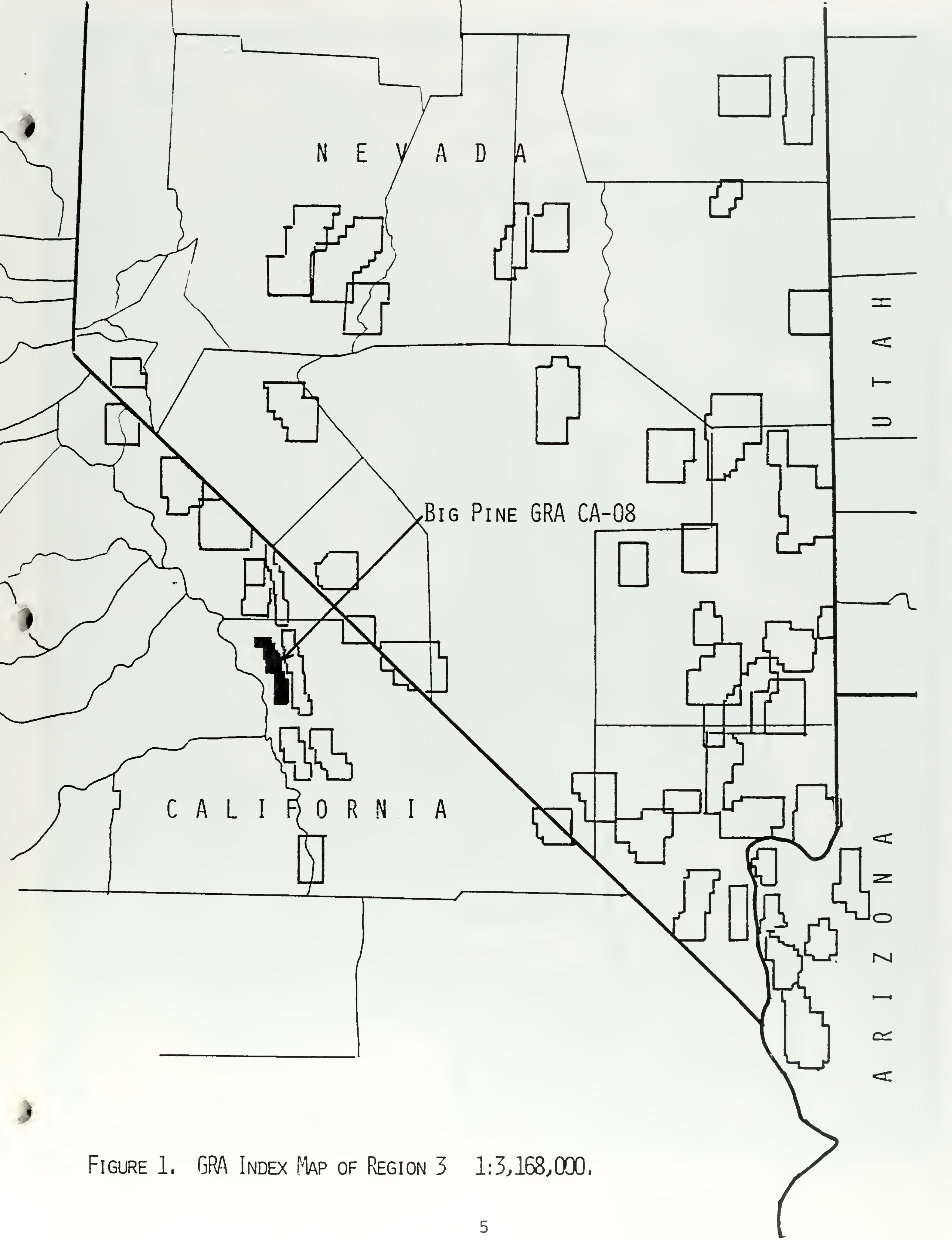
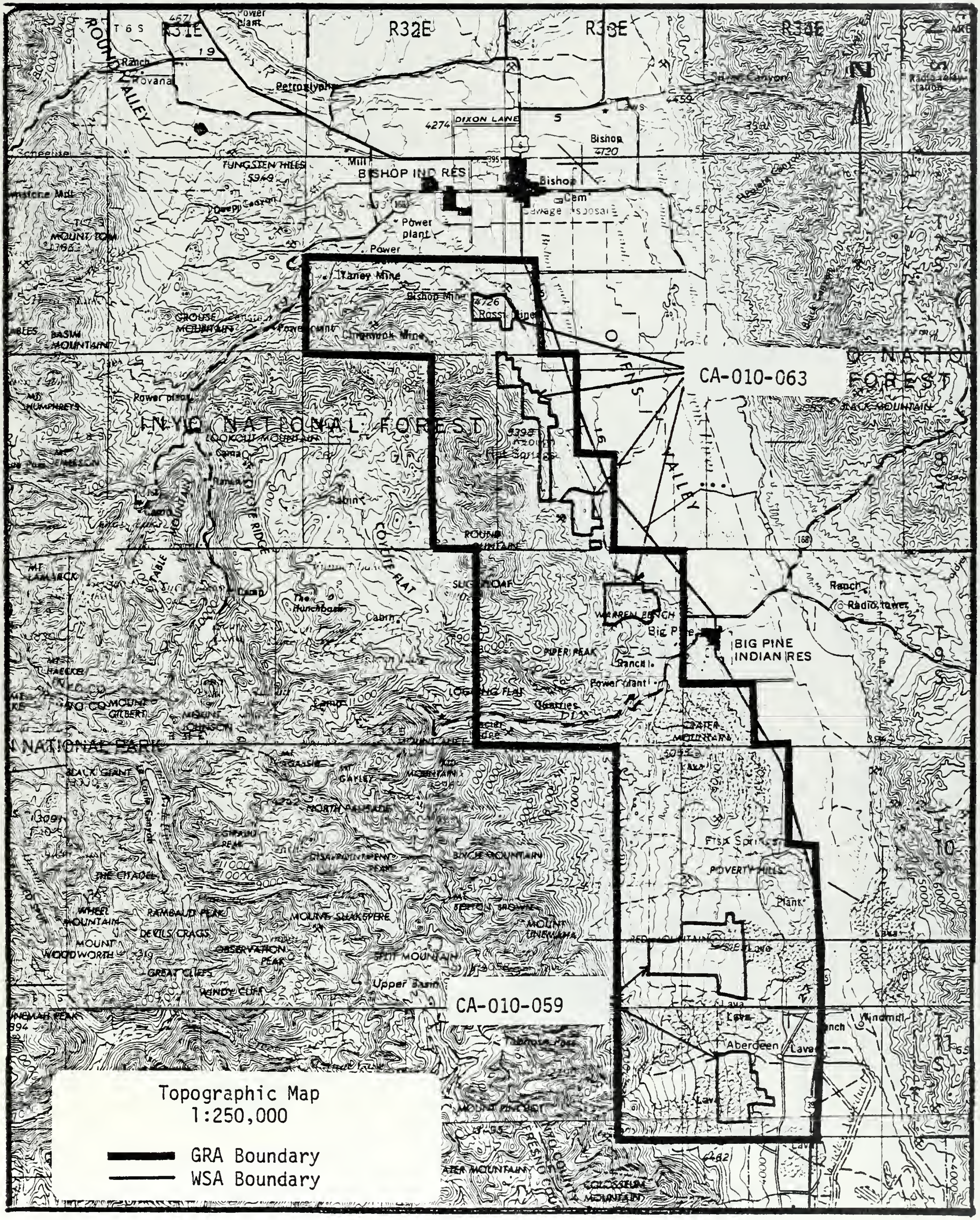


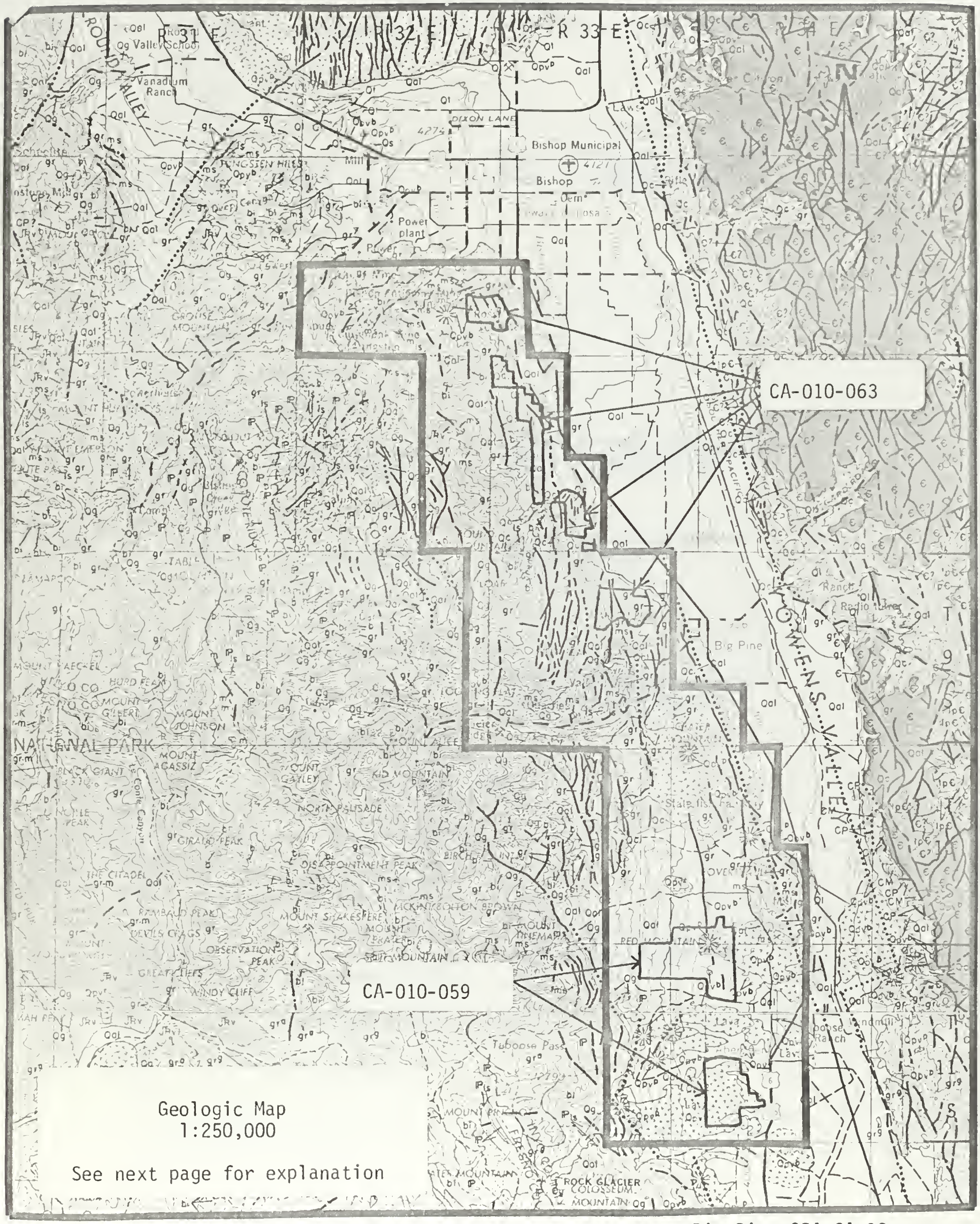
Figure 1. GRA Index Map of Region 3 1:3,168,000.



Mariposa and Fresno Sheets

Big Pine GRA CA-08

Figure 2



Mariposa Sheet, Strand (1967); Fresno Sheet, Mathews and Burnett (1965)

Big Pine GRA CA-08

Figure 3

EXPLANATION

Era	Period	Epoch	SEDIMENTARY AND METASEDIMENTARY ROCKS			IGNEOUS AND META-IGNEOUS ROCKS	
CENOZOIC	QUATERNARY	Recent	Qs	Dune sand			
			Qal	Alluvium			
			Qsc	Stream channel deposits	GREAT VALLEY	Qrv	Recent volcanic: Qrv^r —rhyolite; Qrv^a —andesite; Qrv^b —basalt; Qrv^p —pyroclastic rocks
			Qf	Fan deposits	GREAT VALLEY		
			Qb	Basin deposits	GREAT VALLEY		
			Qst	Salt deposits			
			Ql	Quaternary lake deposits			
			Qg	Glacial deposits			
			Qt	Quaternary nonmarine terrace deposits			
		Pleistocene	Qm	Pleistocene marine and marine terrace deposits		Qpv	Pleistocene volcanic: Qpv^r —rhyolite; Qpv^a—andesite; Qpv^b —basalt; Qpv^p —pyroclastic rocks
			Qc	Pleistocene nonmarine			
			QP	Plio-Pleistocene nonmarine			Quaternary and/or Pliocene cinder cones
	TERTIARY	Pliocene	Pc	Undivided Pliocene nonmarine			
			Puc	Upper Pliocene nonmarine			
			Pu	Upper Pliocene marine		Pv	Pliocene volcanic: Pv^r –rhyolite; Pv^a—andesite; Pv^b —basalt; Pv^p —pyroclastic rocks
			Pmlc	Middle and/or lower Pliocene nonmarine			
			Pml	Middle and/or lower Pliocene marine			
		Miocene	Mc	Undivided Miocene nonmarine			
			Muc	Upper Miocene nonmarine			
			Mu	Upper Miocene marine		Mv	Miocene volcanic: Mv^r —rhyolite; Mv^a —andesite; Mv^b —basalt; Mv^p —pyroclastic rocks
			Mmc	Middle Miocene nonmarine			
			Mm	Middle Miocene marine			
			Ml	Lower Miocene marine			
		Oligocene	Φc	Oligocene nonmarine		Φv	Oligocene volcanic: $Φv^r$—rhyolite; $Φv^a$ —andesite; $Φv^b$ —basalt; $Φv^p$—pyroclastic rocks
			Φ	Oligocene marine			
		Eocene	Ec	Eocene nonmarine		Ev	Eocene volcanic: Ev^r —rhyolite; Ev^a —andesite; Ev^b —basalt; Ev^p —pyroclastic rocks
			E	Eocene marine			
		Paleocene	Epc	Paleocene nonmarine			
			Ep	Paleocene marine			

Paleocene marine

EXPLANATION CONT.

Undivided

- QTc — Cenozoic nonmarine
- Tc — Tertiary nonmarine
- Tl — Tertiary lake deposits
- Tm — Tertiary marine
- QTv — Cenozoic volcanic: QTvʳ —rhyolite; QTvᵃ—andesite: QTvᵇ —basalt; QTvᵖ —pyroclastic rocks
- Tgr — Tertiary granitic rocks
- Ti — Tertiary intrusive (hypabyssal) rocks: Tiʳ – rhyolite; Tiᵃ – andesite; Tiᵇ – basalt
- Tv — Tertiary volcanic: Tvʳ —rhyolite; Tvᵃ —andesite; Tvᵇ —basalt; Tvᵖ —pyroclastic rocks

MESOZOIC

CRETACEOUS

- K — Undivided Cretaceous marine
- Ku — Upper Cretaceous marine
- Kl — Lower Cretaceous marine

JURASSIC

- Jk — Knoxville Formation
- Ju — Upper Jurassic marine
- Jml — Middle and/or Lower Jurassic marine

TRIASSIC

- Ʈ — Triassic marine

Franciscan Formation

- KJf
- KJfv — Franciscan volcanic and metavolcanic rocks
- gr — Mesozoic granitic rocks: grᵃ-granite and adamellite; grᵍ-granodiorite; grᵗ-tonalite and diorite
- bi — Mesozoic basic intrusive rocks
- ub — Mesozoic ultrabasic intrusive rocks
- JƮv — Jura-Trias metavolcanic rocks

UNDIVIDED

- m, ls — Pre-Cretaceous metamorphic rocks (ls = limestone or dolomite)
- ms — Pre-Cretaceous metasedimentary rocks
- P, ls — Paleozoic marine (ls = limestone or dolomite
- mv — Pre-Cretaceous metavolcanic rocks
- gr-m — Pre-Cenozoic granitic and metamorphic rocks
- Pv — Paleozoic metavolcanic rocks

PALEOZOIC

PERMIAN

- P — Permian marine
- Pv — Permian metavolcanic rocks

CARBONIFEROUS

- C — Undivided Carboniferous marine
- Cv — Carboniferous metavolcanic rocks
- CP — Pennsylvanian marine
- CM — Mississippian marine

DEVONIAN

- D — Devonian marine
- Dv — Devonian metavolcanic rocks
- Dv? — Devonian and pre-Devonian? metavolcanic rocks

SILURIAN

- S — Silurian marine
- pSs — Pre-Silurian meta-sedimentary rocks
- pS — Pre-Silurian metamorphic rocks
- pSv — Pre-Silurian metavolcanic rocks

ORDOVICIAN

- O — Ordovician marine

CAMBRIAN

- € — Cambrian marine
- €? — Cambrian – Precambrian marine

PRECAMBRIAN

- p€c — Precambrian igneous and metamorphic rock complex
- p€ — Undivided Precambrian metamorphic rocks; p€g = gneiss, p€s = schist
- p€gr — Undivided Precambrian granitic rocks
- lp€ — Later Precambrian sedimentary and metamorphic rocks
- p€an — Precambrian anorthosite
- ep€ — Earlier Precambrian metamorphic rocks

II. GEOLOGY

The Big Pine GRA is in Inyo County and includes a six mile wide rectilinear area along the northwest-trending Eastern Sierra Nevada escarpment from Bishop south to two miles north of Independence.

The predominant rock units are Cretaceous plutons which interlock to form the Sierra Nevada Batholith. Numerous roof pendants and septa comprised of Paleozoic metasediments and Mesozoic metavolcanics occur in the intrusions in the general region of the GRA.

Pre-batholithic regional folding and faulting of the older rocks have been identified with difficulty. Batholithic deformation of the Paleozoic and Mesozoic rocks is of a smaller scale and closely associated geometrically with the configuration of the adjacent pluton.

Upwarping, tilting and faulting of the Sierra Nevada began during the early Pleistocene, but did not culminate in the uplift to the present elevations until Late Pleistocene. Range front faults, especially in the southern portion of the study area are currently active, displacing recent alluvium.

Early Pleistocene volcanism and glaciation are marked by the deposition of olivine basalt along the range front and basalt and glacial till in the Tungsten Hills.

1. PHYSIOGRAPHY

The Big Pine GRA lies along the eastern edge of the Sierra Nevada Province where it comes in contact with the Basin and Range Province. Elevations of peaks in the Sierra Nevada are above 11,000 feet. Drainage of the Sierra Nevada is predominantly perpendicular to the northwest trend of the range front, into the Owens Valley to the east at an elevation of about 4,500 feet.

The Sierra Nevada edge between the Tungsten Hills and Fish Springs Hill is a broad convex bulge having a gentle slope of about 10°. The southern portion of the bulge slopes into the foothills southeast of Big Pine (Bateman, 1965). The escarpments in this area are much steeper than those to the north.

2. ROCK UNITS

The oldest rocks in the study area are unnamed Paleozoic metasediments which occur as roof pendants or septa within the numerous Cretaceous granitic plutons. These metasediments consist of biotite schist, marble, calc-hornfels and

quartzite. The next oldest rocks are Jurassic-Triassic mafic metavolcanics which outcrop in the Tungsten Hills area. There are only very few and very small exposures of either these rocks in the WSAs and close to them (Bateman, 1965, Plates 3 and 4).

Numerous granitic bodies ranging in composition from quartz monzonite to much more mafic rocks of the Sierra Nevada batholith were intruded during the Cretaceous. The earliest intrusions were mafic with a wide range of compositions, but only small remnants of them remain and they are lumped together in Bateman's (1965) mapping under the heading of "diorite". They may have been relatively small bodies when they were intruded. Later, in middle and late Cretaceous, at least half a dozen large granitic bodies were intruded, and these now are by far the predominant rock types in the terrane. The younger intrusive bodies are the source of mineralizing solutions that formed the tungsten ore bodies that are the principal metallic deposits of the region.

Basalt dikes and necks were intruded, and flows extruded, during the early Pleistocene throughout the study area. In the Tungsten Hills north of the GRA early Pleistocene glacial till deposits crop out near the basalt flows.

Older, dissected Pleistocene alluvial fan and lakebed deposits occur along the northern and northwestern border of the Big Pine GRA.

3. STRUCTURAL GEOLOGY AND TECTONICS

The oldest structures preserved in the region are remnants of folds within the Paleozoic metasediment and Mesozoic metavolcanic roof pendants and septa. Deformation of these rocks occurred prior to the granitic intrusive activity and also as adjustment to their emplacement.

The regional compressional forces which caused the folding and faulting of the pre-batholithic strata probably began in Triassic time and ended in late Jurassic-early Cretaceous time. Folds produced during the pre-batholithic regional compressional deformation usually have nearly horizontal axes which parallel the north-northwest regional trend. These folds extend many miles and show no geometric relation to bordering granitic intrusives. Folds formed by the intrusive activity are smaller with steeply dipping axes trending in directions that are geometrically related to the configuration of the bordering intrusives (Bateman, 1965).

Pre-batholithic faults within the roof pendants are generally parallel to the northwest regional trend and are very difficult to distinguish. Parallel cleavage in the walls of some faults indicates compressional formation. Linear surface depressions along the traces of faults, resulting from a long

period of erosion, are thought by Bateman (1965) to predate the uplift of the Sierra Nevada.

A regional system of northwest and northeast conjugate steep joints occur in all the granitic rocks, and cross boundaries between different intrusive masses without deflection. These joints reflect regional stress which was very likely horizontal. Minor movement on several of these joints indicates that they may be incipient shears.

The northern portion of the study area is predominantly an upwarping with relatively gentle slopes. From Crater Mountain south, steep escarpments are the result of Pliocene normal faulting. These escarpments are formed by an interconnecting system of curved and straight-line segments that trend predominantly northwest. Numerous range front faults are still active today as evidenced by the displacement of recent alluvial deposits.

4. PALEONTOLOGY

None of the lithologies within the Big Pine GRA are favorable for preservation of paleontological resources. The only potential is for Quaternary biota within alluvium (Qal). Metasedimentary pre-Cretaceous rocks, which occur in scattered outcrops in the area, are not known to contain fossils.

5. HISTORICAL GEOLOGY

During Paleozoic time a thick sequence of marine sediments was deposited in the area. Carbonate facies and clastic facies overlapped indicating a transitional zone environment.

Mesozoic volcanics were deposited over these sediments probably at the onset of the regional compressional tectonic forces which folded and faulted these rocks during the Triassic.

The folded and faulted sediments and volcanics were intensly metamorphosed and deformed by the intrusion of numerous Cretaceous plutons of the Sierra Nevada Batholith. Further folding and faulting of the older rocks occurred at this time. After the plutons had crystallized, joint patterns within them developed due to regional stresses.

Upwarping and west tilting of the Sierra Nevada block began during the early Pleistocene and continued intermittently until the middle Pleistocene.

Volcanism took place concurrently with the increased tectonism, producing the deposition of olivine basalt predominantly along the range front. A period of glaciation

also occurred at this time. Glacial till deposits are located in the Tungsten Hills (Bateman, 1965).

Near the end of the Pleistocene, a large increase in tectonic activity produced the faulting responsible for most of the present structure and topography. These faults are still active today as evidenced by the displacement of recent sediments along the range front.

III. ENERGY AND MINERAL RESOURCES

A. METALLIC MINERAL RESOURCES

WSA CA 010-063 is separated into six non-contiguous (or almost non-contiguous in one case) segments. In order to be able to refer to them, each segment has here been assigned a letter designation, in reverse alphabetical order, starting with Z for the northernmost segment and ending with U for the southernmost. WSA CA 010-059 consists of only two segments, which will be referred to as the north and south segments. These designations are used only on the Metallic Minerals Land Classification-Mineral Occurrence Map.

1. Known Mineral Deposits

The Bishop Antimony mine lies just west of segment Z of WSA CA 010-063, about a quarter of a mile from the WSA. The ore is in pods along an east-west fault in Paleozoic marble (Norman and Stewart, 1951). Neither the fault nor the marble appear to extend into the WSA segment (Bateman, 1965, Plate 3).

The principal metallic mineral found in the GRA and in this region of the Sierra Nevada is tungsten. There are no known deposits within the WSAs, although the Rossi mine lies in a small roof pendant of marble just outside the north boundary of segment Z of WSA CA 010-063.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

In Sec. 17, T 8 S, R 33 E, just west of Keough Hot Spring in segment X of WSA CA 010-063 are two tungsten prospects. They are apparently within a roof pendant of older mafic intrusives in granite (Bateman, 1965, Plate 3).

In Sec. 20, T 8 S, R 33 E is the Buckshot prospect, perhaps inside or perhaps outside the boundary of segment X of WSA CA 010-063 (Bateman, 1965, Plate 4). This is scheelite in tactite, prospected only by shallow pits (Norman and Stewart, 1951).

3. Mining Claims

There are no patented claims in the GRA.

Unpatented claims plot within the south end of segment X of WSA 010-063. At least some of these probably cover the Buckshot prospect. Apparently there are no claims covering the prospects west of Keough Hot Spring. Unpatented claims plot within segment W of WSA 010-063.

Unpatented claims that plot within segment U of WSA CA 010-063 probably are for nonmetallic minerals.

Unpatented claims are quite numerous in the northeast corner of the northern segment of WSA CA 010-059. They are almost certainly on cinder deposits around Red Mountain.

4. Mineral Deposit Types

Deposits of tungsten, the only metallic element known to occur within the WSAs of the Big Pine GRA, occur in roof pendants in the Sierra Nevada intrusives. According to Bateman (1965), with one or two exceptions they are contact metasomatic tactite deposits, and his text implies that only the sedimentary strata are contact metamorphosed. The tungsten prospects west of Keough Hot Spring, lying as they seem to do in mafic rocks, do not fit this pattern but it may be that they are in contact metamorphosed sediment bodies too small to portray at Bateman's (1965) map scale of 1:62,500.

5. Mineral Economics

The price of tungsten is subject to wide variations dependent upon demand and also upon the availability of foreign supplies. When the price is low only large well-established mines can continue to operate. When the price is high small mines tend to come into production, particularly since mineral processing techniques that produce relatively clean scheelite concentrates are available and simple enough for small operations.

Therefore, while tungsten mines and prospects may lie idle for years, they may also spring into production during periods of high metal prices.

Nearly half of all antimony is used as an alloying constituent of lead and other metal. In this application the largest part goes into the lead plates of automobile and other batteries, but much cable sheaths, tank linings, is used in typemetal, solder and ammunition. In chemical combination with other elements it is used as a flame retardant, in rubber and plastic products, and ceramics. The United States uses about 50,000 short tons annually, but produces only about 1,000 tons and nearly all of that as a byproduct of the treatment of other metals -- principally silver from the Coeur d'Alene district of Idaho. The principal world producers are China, the Republic of South Africa and the U.S.S.R. Antimony is listed as a strategic and critical metal. By the year 2000 United States antimony consumption is forecast to increase by about one half over the present consumption,

while domestic production remains about the same. The price of antimony at the end of 1982 was 95 cents per pound.

More than half of all tungsten used is in the form of tungsten carbide, a hard and durable material used in cutting tools, wear-resistant surfaces and hard-faced welding rods. Lesser quantities are used in alloy steels, in light bulb filaments, and in chemicals. World production of tungsten is nearly 100 million pounds annually, of which the United States produces somewhat more than six million pounds, while using more than 23 million pounds. The shortfall is imported from Canada, Bolivia, Thailand and Mainland China, as well as other countries. Tungsten is a strategic and critical metal. United States demand is projected to about double by the year 2000, and most of the additional supply will probably be imported, because large reserves are in countries in which profitability is not a factor -- they need foreign exchange, and therefore sell at a price that few domestic mines can match. Tungsten prices F.O.B. mine are quoted for "short ton units", which are the equivalent of 20 pounds of contained tungsten. At the end of 1982 the price of tungsten was about $80 per short ton unit.

B. NONMETALLIC MINERAL RESOURCES

1. Known Mineral Deposits

In Sec. 11, T 9 S, R 33 E, within segment U of WSA CA 010-063, is the Sierra White quarry. Norman and Stewart (1951) describe this as a zone of feldspar 20 to 30 feet wide that had produced 4,000 tons by early 1950. Bateman (1965, plate 4) shows a pegmatite dike in about the correct position to be the one mined. Just north of the segment of the WSA is the Nebicite feldspar-kaolinite deposit from which 1,000 tons had been mined before 1950 (Norman and Stewart, 1951); it is probably continuation of the same pegmatite dike mined at Sierra White.

Perlite has been mined in Secs. 19 and 30, T 10 S, R 34 E, from the Fish Springs Property (Norman and Stewart, 1951) for thirty years or more. In a helicopter flyby during field verification of the New York Butte GRA, it appeared that the plant was still operating in 1982. This deposit is not within either WSA of the GRA.

Diatomite occurs in a four-foot thick bed in Sections 23 and 26, T 10 S, R 34 E, on the east edge of the GRA. About 600 tons of diatomite has been produced (Cleveland, 1958).

2. Known Prospects, Mineral Occurrences and Mineralized Areas

No nonmetallic prospects or mineral occurrences were so designated in the literature reviewed.

3. Mining Claims, Leases and Material Sites

Unpatented mining claims in and north of segment U of WSA CA 010-063 are probably on the Sierra White and Nebicite feldspar deposits.

Numerous unpatented mining claims in the northeast corner of the northern segment of WSA 010-059 undoubtedly were located to cover extensive volcanic cinder deposits on and around Red Mountain.

No material sites are known within the WSAs.

4. Mineral Deposit Types

The feldspar deposits of Sierra White in segment U of WSA CA 010-063 and Nebicite are a long but narrow pegmatite dike, some of the last crystallizing components of one of the Sierra Nevada intrusions. The dike can be expected to be long (and is so mapped by Bateman, 1965, Plate 4) and to extend to considerable depth. However, the composition of the vein may differ from place to place, so that not all of it is necessarily saleable feldspar.

The perlite deposits are part of a Quaternary rhyolite plug, which cooled rapidly enough that a relatively high content of water was trapped in the volcanic glass. It is this water that expands to cause the perlite to "pop" when it is heated, and thus make a very porous, light-weight material.

The volcanic cinder deposits on and around Red Mountain are extensive and probably thick. Red Mountain is a cinder cone built principally of cinders ejected from a central throat.

5. Mineral Economics

Feldspar is, in general, a low-priced commodity, so it can rarely be mined underground. The narrowness of the dike in which the feldspar occurs at the Sierra White mine, 30 feet maximum, sharply limits the depth of open pits that can be dug on it -- safety requires that the pit walls be sloped but this sloping requires removal of waste, which increases the cost. This aspect can be avoided for a limited period if the vein continues in ore laterally -- the pit is extended in length rather than downward -- but

eventually the dike must end in either direction.

Perlite deposits are not uncommon, but they are not common either and do not occur at all except in volcanic terranes. The long productive life of the Fish Springs deposit is evidence that it can compete with other perlite sources for the Los Angeles area market.

Deposits of volcanic cinders are relatively common, and the price for them is low. Transportation cost frequently is higher than the F.O.B. pit price. Extensive cinder deposits are known, and currently being mined, much closer to the major market in the Los Angeles area than are the deposits in the Big Pine GRA. Because of transportation costs, it is unlikely that cinders can be mined economically in Big Pine.

Nearly all feldspar is used in either glassmaking or the ceramic industry but small amounts are used as a powdered abrasive, frequently in household applications. The United States produces nearly three-quarters of a million short tons annually and uses a little less than this, the remainder being exported. United States consumption is forecast to increase to well over one million tons by the year 2000, with domestic production supplying all or most of this. Feldspar is a very common mineral everywhere in the world, and the only reason for any increase in imports into the United States will be lower foreign production costs. The price of feldspar F.O.B. mine is about $30 per ton.

Perlite is a glassy volcanic rock that has the unusual property of expanding to about 20 times its original volume when heated to the proper temperature and almost all of it is used in the expanded form. The largest use of perlite, accounting for more than half of United States consumption, is in construction where it is used as lightweight and insulating aggregate in concrete, alone as an insulator, as an aggregate in fireproof plastic mixes for structural steel, and in other applications. About 15 percent of usage is as a filter aid in many food and beverage applications. Less than 10 percent is used in agriculture as a soil conditioner, and a great variety of other applications consumes the remainder. The United States uses about 600,000 short tons annually and produces this much plus a little more that is exported. Consumption is forecast to about double by the year 2000, with production keeping up with demand. The price of crude perlite is about $25 per short ton.

For statistical purposes pumice, volcanic cinder and scoria are treated together because in most applications they are interchangeable; the word "pumice" as used here includes the other materials. Because of its porous nature and resultant light weight (some pumice will float

on water) about 40% of all pumice production is used as aggregate in making light-weight concrete for construction purposes. An equal amount is used as aggregate in road construction. A small amount is used in abrasives, while the remainder is used, mostly in finely-ground form, in a multitude of applications such as absorbents, carriers for insecticides, decolorizers and purifying agents, fillers and extenders for paints, and many others. United States consumption is about 4.5 million short tons annually, nearly all of which is produced domestically and most of which is produced within a very few hundred miles of the point of use because it is a high-volume, low-unit-price material. A small quantity of pumice for specialized uses is imported. United States demand for pumice is forecast to more than double by the year 2000, with domestic production keeping up with demand. In recent years the F.O.B. mine price for pumice as such has been about $4 per ton, while the price for the somewhat more common volcanic cinders has been about $3 per ton.

C. ENERGY RESOURCES

Uraniun and Thorium Resources

1. Known Mineral Deposits

   There are no known uranium or thorium deposits within or near the GRA.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

   There are no known uranium or thorium prospects or occurrences within or near the GRA.

3. Mining Claims

   There are no known uranium or thorium claims within the GRA.

4. Mineral Deposit Types

   Deposit types cannot be discussed for the GRA as there are no known occurrences of these minerals within or near the GRA.

5. Mineral Economics

   There appears to be no economic value for radioactive minerals as there are no uranium or thorium occurrences within the GRA.

Uranium in its enriched form is used primarily as fuel for nuclear reactors, with lesser amounts being used in the manufacture of atomic weapons and materials which are used for medical radiation treatments. Annual western world production of uranium concentrates totaled approximately 57,000 tons in 1981, and the United States was responsible for about 30 percent of this total, making the United States the largest single producer of uranium (American Bureau of Metal Statistics Inc., 1982). The United States ranks second behind Australia in uranium resources based on a production cost of $25/pound or less. United States uranium demand is growing at a much slower rate than was forecast in the late 1970s, because the number of new reactors scheduled for construction has declined sharply since the accident at the Three Mile Island Nuclear Plant in March, 1979. Current and future supplies were seen to exceed future demand by a significant margin and spot prices of uranium fell from $40/pound to $25/pound from January, 1980 to January, 1981 (Mining Journal, July 24, 1981). At present the outlook for the United States uranium industry is bleak. Low prices and overproduction in the industry have resulted in the closures of numerous uranium mines and mills and reduced production at properties which have remained in operation. The price of uranium at the end of 1982 was $19.75/pound of concentrate.

Thorium is used in the manufacture of incandescent gas mantles, welding rods, refractories, as fuel for nuclear power reactors and as an alloying agent. The principal source of thorium is monazite which is recovered as a byproduct of titanium, zirconium and rare earth recovery from beach sands. Although monazite is produced from Florida beach sands, thorium products are not produced from monazite in the United States. Consequently, thorium products used in the United States come from imports, primarily from France and Canada, and industry and government stocks. Estimated United States consumption of thorium in 1980 was 33 tons, most of which was used in incandescent lamp mantles and refractories (Kirk, 1980b). Use of thorium as nuclear fuel is relatively small at present, because only two commercial thorium-fueled reactors are in operation. Annual United States demand for thorium is projected at 155 tons by 2000 (Kirk, 1980a). Most of this growth is forecast to occur in nuclear power reactor usage, assuming that six to ten thorium-fueled reactors are on line by that time. The United States and the rest of the world are in a favorable position with regard to adequacy of thorium reserves. The United States has reserves estimated at 218,000 tons of ThO_2 in stream and beach placers, veins and carbonatite deposits (Kirk, 1982); and probable cumulative demand in the United States as of 2000 is estimated at only 1800 tons (Kirk, 1980b). The price of thorium oxide at the end of 1981 was $16.45 per pound.

Oil and Gas Resources

There are no oil and gas fields, hydrocarbon shows in wells, or surface seeps in the region; nor are there any Federal oil and gas leases in the immediate region. The geologic environment -- intrusive and metamorphic rocks or very young volcanics and alluvium -- is not suitable for the occurrence of oil and gas.

There is no oil and gas lease map, nor oil and gas occurrence and classification map for this report.

Geothermal Resources

1. Known Geothermal Deposits

At the base of the Sierran range front, 12 miles north of Big Pine and just outside segment X of WSA CA 010-063, 51°C Keough Hot Springs flows 2000 l/min and has a low salinity of 510 mg/l. Its flow has been used for many years in a resort swimming pool.

2. Known Prospects, Geothermal Occurrences, and Geothermal Areas

Due east of Keough Hot Springs, on the opposite side of the valley and beyond the GRA, there is an unnamed spring (29°C) (NOAA, 1980).

3. Geothermal Leases

There are no Federal leases or lease applications within the GRA region. No geothermal lease map is included with the report.

4. Geothermal Deposit Types

There are no deposits within the GRA, but the Keough Hot Spring occurrence is present due to the upward circulation of thermal waters along a permeable segment of the Owens Valley fault zone.

5. Geothermal Economics

The Keough Hot Spring temperature (51°C) and flow (2000 l/min) are used commercially as a resort attraction. Development of the existing resource by means of shallow drilling would probably increase the beneficial use in both quantity of water and very possibly in temperature also.

Geothermal resources are utilized in the form of hot water or steam normally captured by means of drilling wells to a depth of a few feet to over 10,000 feet in depth. The fluid temperature, sustained flow rate and water chemistry characteristics of a geothermal reservoir determine the depth to which it will be economically feasible to drill and develop each site.

Higher temperature resources (above 350°F) are currently being used to generate electrical power in Utah and California, and in a number of foreign countries. As fuel costs rise and technology improves, the lower temperature limit for power will decrease appreciably -- especially for remote sites.

All thermal waters can be beneficially used in some way, including fish farming (68°F), warm water for year around mining in cold climates (86°F), residential space heating (122°F), greenhouses by space heating (176°F), drying of vegetables (212°F), extraction of salts by evaporation and crystallization (266°F), and drying of diatomaceous earth (338°F).

Unlike most mineral commodities remoteness of resource location is not a drawback. Domestic and commercial use of natural thermal springs and shallow wells in the Basin and Range province is a historical fact for over 100 years.

Development and maintenance of a resource for beneficial use may mean no dollars or hundreds of millions of dollars, depending on the resource characteristics, the end use and the intensity or level of use.

D. OTHER GEOLOGICAL RESOURCES

No other geological resources are known in the WSAs.

E. STRATEGIC AND CRITICAL MINERALS AND METALS

A list of strategic and critical minerals and metals provided by the BLM was used as a guideline for the discussion of strategic and critical materials in this report.

The Stockpile Report to the Congress, October 1981-March 1982, states that the term "strategic and critical materials" refers to materials that would be needed to supply the industrial, military and essential civilian needs of the United States during a national emergency and are not found or produced in the United States in sufficient quantities to meet such need. The report does not define a distinction between strategic and critical minerals.

Tungsten, a strategic and critical metal, has been produced within the GRA. Tungsten prospects are known in WSA CA 010-063.

IV. LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

Bateman's work (1956 and 1965) covers nearly all of the GRA and the WSAs, while Moore's (1963) mapping covers the southernmost end and the southern segment of WSA CA 010-059. Bateman, in particular, made a specific effort to locate, examine and plot on his maps every possible mineral occurrence. The geologic mapping of both Bateman and Moore is good, and detailed to the extent it can be at their scale of 1:62,500. Undoubtedly some of the plutons can be subdivided, and probably will be, but this is not likely to have much bearing on mineralization in the area. Alteration in the sense of the metamorphic and metasomatic effects of the intrusions -- which are related to tungsten mineralization -- have been mapped in some detail. Other styles of alteration, such as argillization that might be related to base- and precious-metal veins has not been mapped, and probably is not extensive or greatly important. Overall, the quantity and quality of geological data available are high, and the quantity and quality of data pertaining to mineral resources are high also. We have a high level of confidence in the data available.

Land classification areas are numbered starting with the number 1 in each category of resources. Metallic mineral land classification areas have the prefix M, e.g., M1-4D. Uranium and thorium areas have the prefix U. Nonmetallic mineral areas have the prefix N. Oil and gas areas have the prefix OG. Geothermal areas have the prefix G. Sodium and potassium areas have the prefix S. The saleable resources are classified under the nonmetallic minerals resource section. Both the Classification Scheme, numbers 1 through 4, and the Level of Confidence Scheme, letters A, B, C and D, as supplied by the BLM are included as attachments to this report. These schemes were used as strict guidelines in developing the mineral classification areas used in this report.

Land classifications have been made here only for the areas that encompass the WSAs. Where data outside a WSA has been used in establishing a classification area within a WSA, then at least a part of the surrounding area may also be included for clarification. The classified areas are shown on the 1:250,000 mylars or the prints of those that accompany each copy of this report. Classification areas N2 and N4 are also shown on the Big Pine 15-minute topographic quadrangle in the GRA file. Other classification areas are so inclusive that similar detailed outlining is not necessary.

WSA CA 010-063 is separated into six non-contiguous (or almost non-contiguous in one case) segments. In order to be able to refer to them unambiguously, each segment has here been assigned a letter designation, in reverse alphabetical order, starting with Z for the northernmost segment and ending with U for the southernmost. WSA CA 010-059 consists of only two segments, which will be referred to as the north and south segments.

In connection with nonmetallic mineral classification, it should be noted that in all instances areas mapped as alluvium are classified as having moderate favorability for sand and gravel, with moderate confidence, since alluvium is by definition sand and gravel. All areas mapped as principally limestone or dolomite have a similar classification since these rocks are usable for cement or lime production. All areas mapped as other rock, if they do not have specific reason for a different classification, are classified as having low favorability, with low confidence, for nonmetallic mineral potential, since any mineral material can at least be used in construction applications.

1. LOCATABLE RESOURCES

a. Metallic Minerals

WSA CA 010-063

M1-1C. This classification area covers all of segment Z, the northernmost, of WSA CA 010-063. The segment is almost entirely exposed granite (Bateman, 1965, Plate 3). Presumably there are areas with thin colluvial cover but these are limited. Very close by are the Bishop Antimony mine and the Rossi tungsten mine, both in metasedimentary roof pendants. The granitic rocks are not favorable hosts for mineralization in this area, which is the reason for the very low favorability for metallic minerals and moderately high level of confidence in this classification.

M2-1C. This classification area covers all of segment Y of WSA CA 010-063. Like segment Z it is mapped as entirely granite (Bateman, 1965, Plate 3), although there are no nearby mines or prospects. The rationale for the classification and confidence rating are the same as for M1-1C.

M3-3C. This classification area covers all of segment X of WSA CA 010-063. The Buckshot tungsten prospect is in or almost in the south end of the segment, and the two tungsten prospects west of Keough Hot Spring are about in the middle of the segment. Roof pendants of mafic rock are exposed throughout most of the length of the segment, and faults are mapped in the north end (Bateman, 1965, Plate 3). The southern half of the segment is mostly covered with alluvium and therefore has not been prospected. The presence of three tungsten prospects is the reason for the moderately favorable classification, and for the moderately high level of confidence in this classification.

M4-1A. This classification area covers all of segment W of WSA CA 010-063. Granite is exposed on a small part of

the segment, but most of the segment is covered by alluvium.

M5-1A. This classification area covers all of segment V of WSA 010-063. Like segment W, it has a little granite exposed but is mostly alluvium-covered.

M6-1C. This classification area covers all of segment U of WSA CA 010-063. The entire segment is underlain by granitic rocks (Bateman, 1965, Plate 4), no doubt partly covered by colluvium. There are no known roof pendants of rock that might be favorable for tungsten deposits. These factors are responsible for the very low favorability and moderate confidence rating.

WSA CA 010-059

M7-2C. This classification area is all of the northern segment of WSA CA 010-059. The segment is entirely covered by Quaternary alluvium and basalt. A mile west of it the terrane is almost entirely granitic intrusive rocks, while a mile south and a mile east is exposed Paleozoic marble. It is quite possible that the contact between intrusives and marble -- a highly favorable environment for tungsten deposits -- lies under this segment of WSA CA 010-059, though it may lie to the east or west. This is the reason for the low favorability classification and the moderate confidence level.

M8-2A. This classification area covers all of the southern segment of WSA CA 010-059. The segment is entirely covered by Quaternary alluvium and basalt. At many places in this region metasedimentary rocks contain tungsten deposits genetically related to the granitic intrusive rocks. Such metasedimentary rocks crop out close to this segment of the WSA. The favorability of these rocks, and the possibility that they are present at depth under this segment of the WSA, are the reasons for the low favorability classification, and since there is only the possibility that the rocks are present, the level of confidence is low.

b. Uranium and Thorium

WSA CA 010-063 and WSA CA 010-059

U1-2B. This land classification covers parts of the WSAs that are in Quaternary alluvial deposits. The area has low favorability at a low confidence level for both uranium and thorium concentration.

Epigenetic sandstone type uranium deposits are prospective

in permeable sand sections of the alluvium, particularly in zones where there is abundant organic matter to reduce and precipitate uranium from ground water. The Cretaceous granitic and acidic volcanic rocks of the surrounding mountains could provide a source for the uranium.

Thorium could occur in the alluvium as resistate mineral concentrations. Monazite and other thorium bearing minerals weathering out of pegmatites in the Cretaceous intrusive could be deposited in the alluvial sands though it is doubtful that the rapid sedimentation along these alluvial slopes would allow enough reworking of the sediments to concentrate the heavier resistate minerals.

U2-2B. This land classification indicates that part of the WSAs has low favorability at a low confidence level for uranium and thorium concentration. Uranium could occur as vein type or pegmatitic deposits in Cretaceous granitic rocks of the WSA. Thorium could occur as primary mineral concentrations in Cretaceous pegmatites though it is not known if there are pegmatites in the granitic rocks of the WSA.

WSA CA 010-059

U3-2B. This land classification covers most of the southern section and part of the northern section of the WSA. These areas have basaltic volcanics at the surface, and these rocks are not favorable environments for uranium occurrences. However, at depth are the same granitic rocks as those of U2-2B, and they have similar potential for uranium and thorium.

c. Nonmetallic Minerals

WSA CA 010-063

N1-2B. This classification area applies to all the segments of WSA CA 010-063 except the small part of segment U covered by N2-4D. No nonmetallic mineral resources are known in classification area N1-2B. However, any rock can be used for construction applications, and almost any mineral material can become an economically saleable material, if a knowledgeable person finds the right market for it. This is the reason for the low favorability and the low level of confidence in this classification.

N2-4D. This classification area is a narrow strip running through segment U, the southernmost segment of WSA CA 010-063. The Sierra White mine produced some thousands of tons of feldspar from a pegmatite vein that Bateman (1965, Plate 4) maps are running through almost the entire

segment.

WSA CA 010-059

N3-2B. This classification area applies to all of both segments of WSA CA 010-059 except that part covered by N4-2D. The reasoning for the classification and confidence is the same as for N1-2B.

N4-2D. This classification area applies to part of the northeast corner of the southern segment of the WSA, where Bateman (1965, Plate 4) shows volcanic cinders forming Red Mountain. There are a great many unpatented claims in this area. There are unquestionably volcanic cinders present, which is the reason for the high confidence rating. No mines or prospects are known to be present; this is the reason for the low favorability.

2. LEASABLE RESOURCES

a. Oil and Gas

WSAs CA 010-059 and CA 010-063

OG1-1D. There has been no serious oil and gas exploration, nor are there any recorded occurrences of oil and gas in this westernmost sector of the Basin and Range province where it meets the Sierra Nevadas. The WSAs are underlain by the granitic Sierra batholith which in some areas is covered by Pliestocene volcanics. There is no evidence of source beds being present in the area.

b. Geothermal

WSA CA 010-063

G1-4D. The 51°C temperature and 2000 l/min flow of Keough Hot Springs have been in commercial use for many years (NOAA, 1980). The area around the spring, and along the fault which provides passage for the ascending thermal waters, is thought to be similarly favorable.

WSAs CA 010-063 and CA 010-059

G2-3C. This classification incorporates the western portion of the Owens Valley fault zone, including alluvium-covered valley floor; that part of the low hills and range underlain by Pleistocene cinder cones and volcanic strata at the north end and most of the south half of the GRA; and the immediately adjacent, highly faulted granite of the range proper. It is within this

zone that the Keough Hot Spring is situated. The presence of the youthful Pleistocene center of volcanic activity is indicitive of the presence of a magma heat source directly below at a shallow depth. The fractured nature of the terrane may allow for an environment conducive for a hot-water hydrothermal convective system.

c. Sodium and Potassium

S1-1D. We recognize no potential for sodium and potassium in WSA CA 010-059 and WSA CA 010-063 because the geological environment is unsuitable for such deposits.

3. SALEABLE RESOURCES

Saleable resources have been covered under the appropriate headings above.

V. RECOMMENDATIONS FOR ADDITIONAL WORK

The tungsten prospects in segment X of WSA CA 010-063 should be examined in the field, on the chance that such examination may provide a better understanding of their potential. Perhaps only a half-hour examination and some notes will be sufficient to record everything of interest, or perhaps detailed mapping and sampling of the prospects and their environs will be needed to obtain a measure of the potential for tungsten ore.

The Buckshot prospect is in an area that Bateman (1965) maps as Quaternary alluvium, which suggests that the mineralization is very poorly exposed. Bulldozing here might be useful, if it can be done. If there are claims on the prospects, that have been held by the same owners for many years, the owners may be able to provide information.

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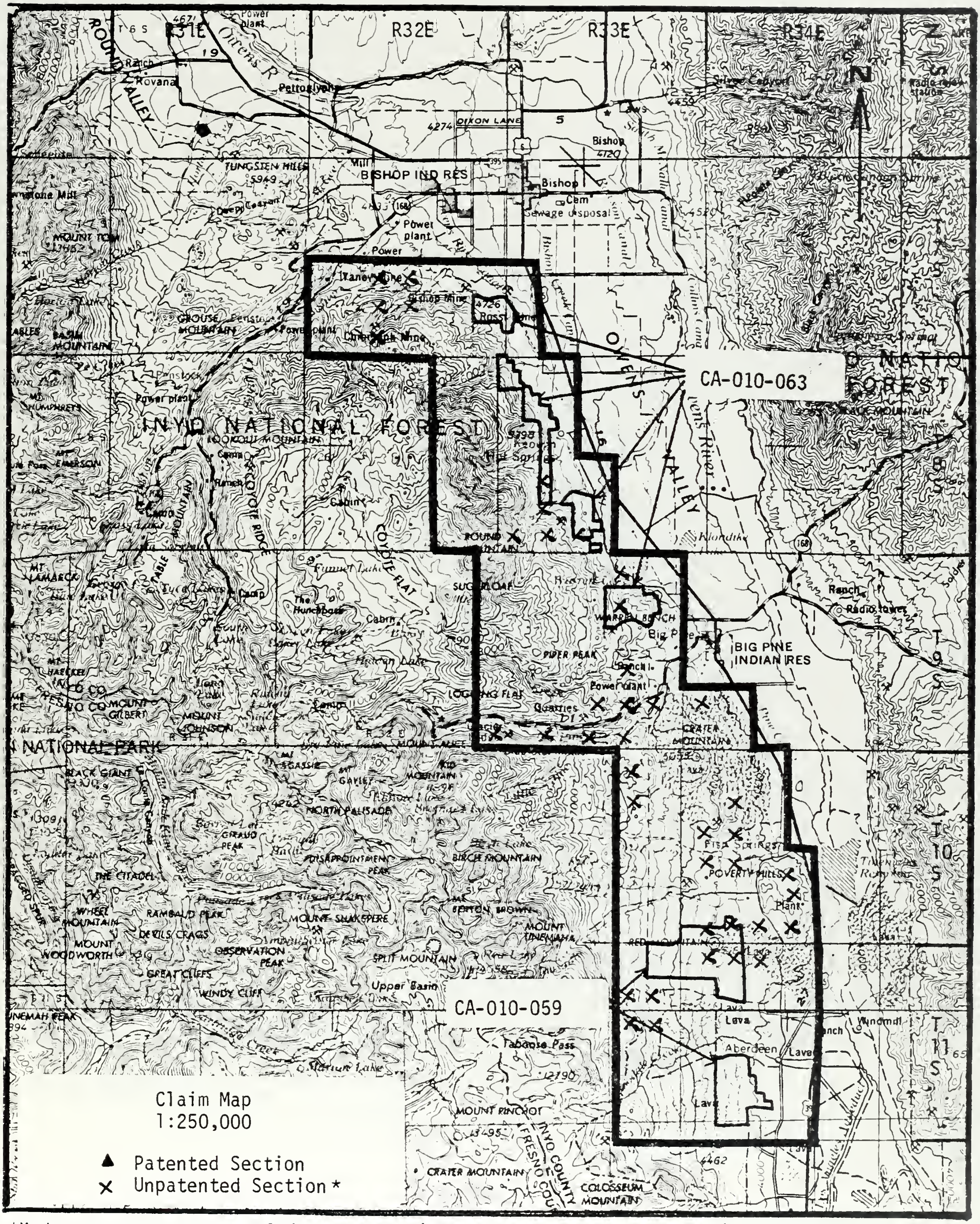
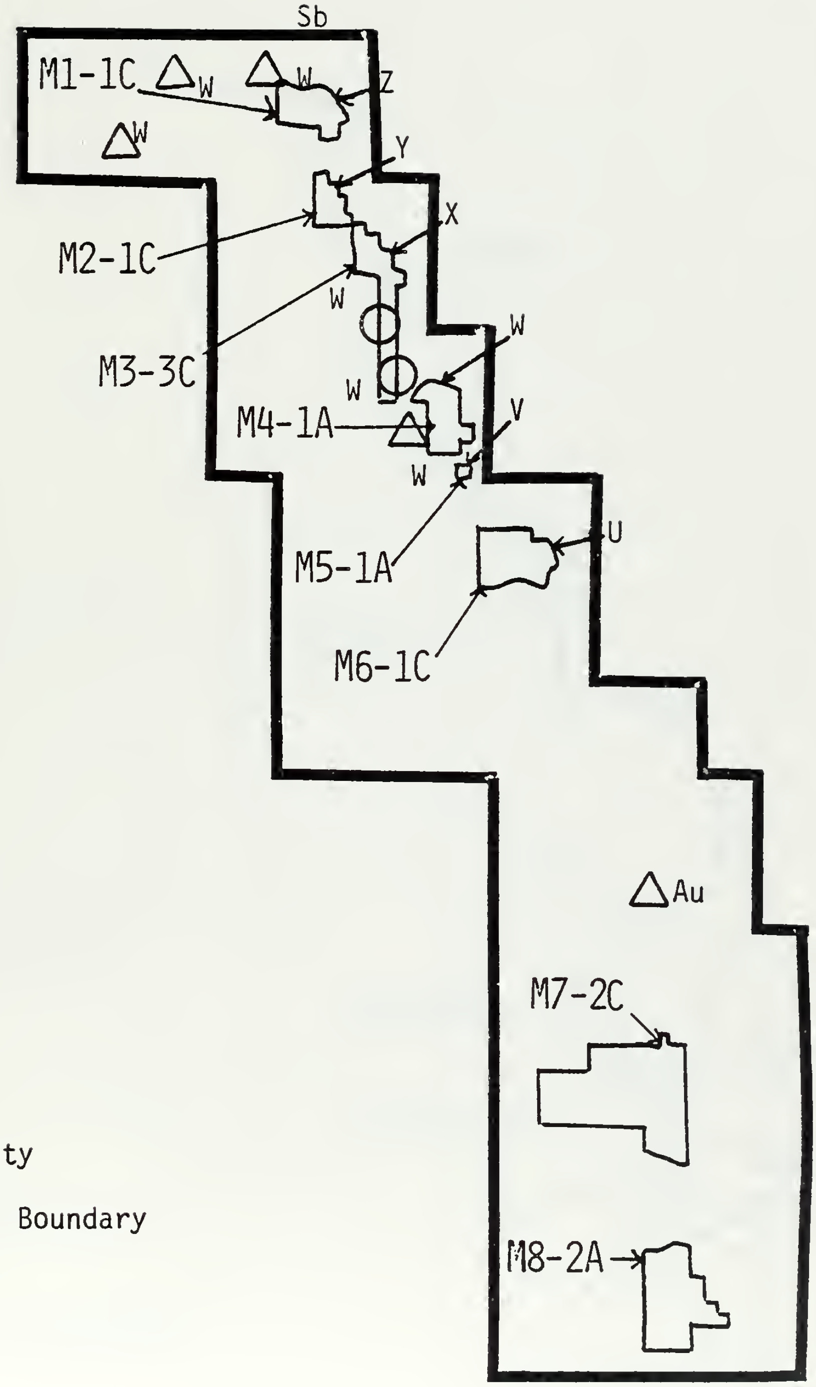


*X denotes one or more claims per section

Big Pine GRA CA-08



EXPLANATION

△ Mine, commodity

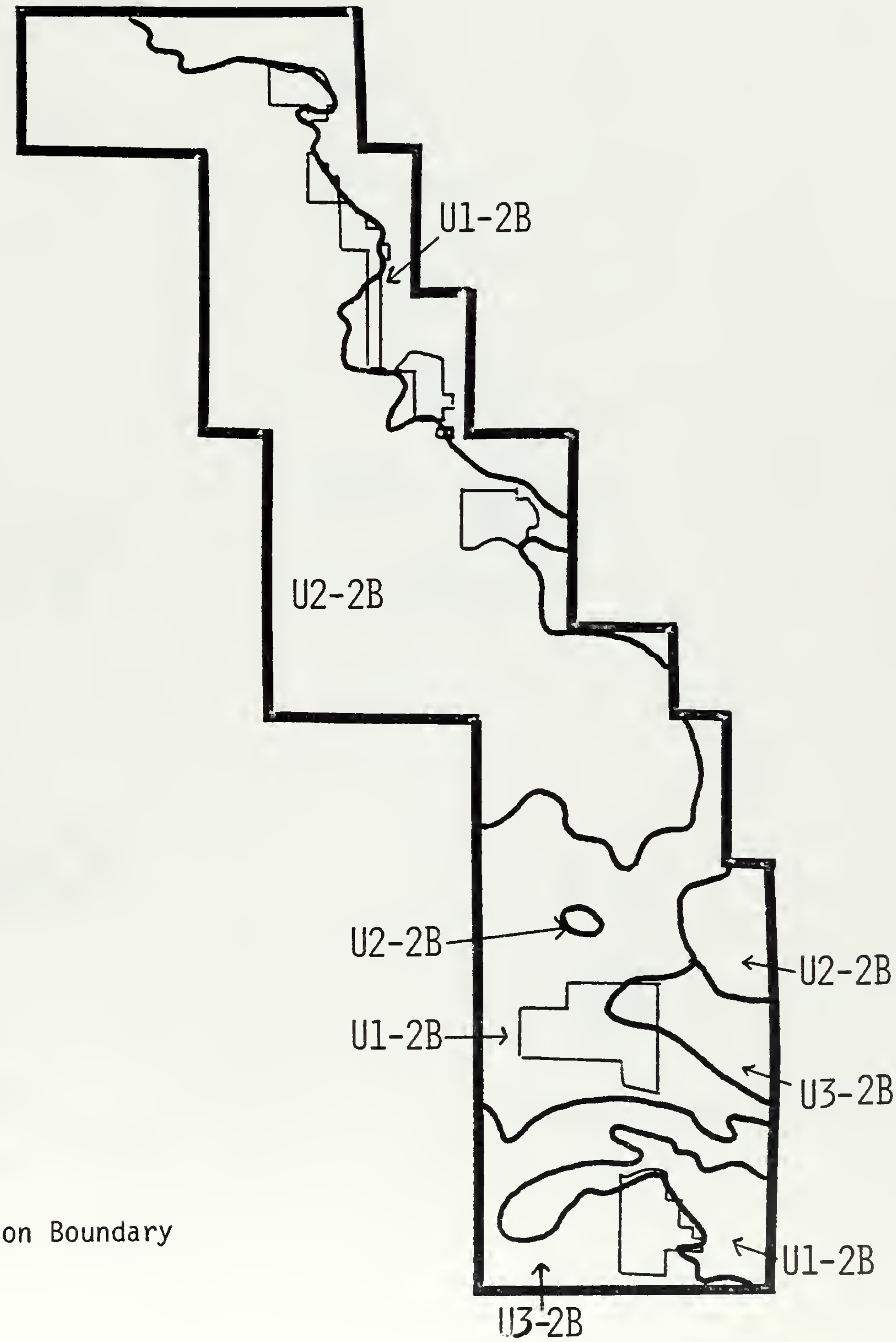
○ Occurrence, commodity

— Land Classification Boundary

— WSA Boundary

Land Classification - Mineral Occurrence Map/ Metallics

Big Pine GRA CA-08
Scale 1:250,000



EXPLANATION

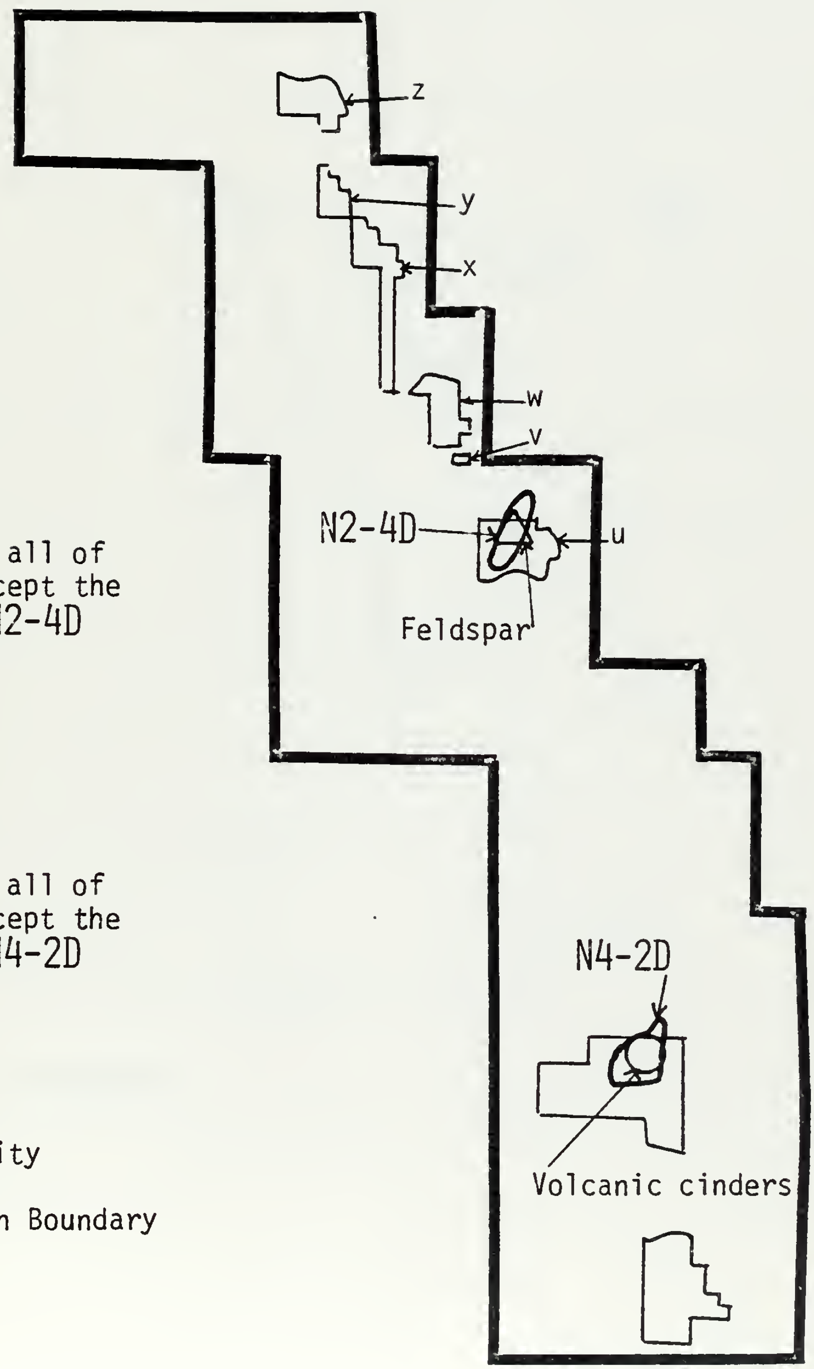
Land Classification Boundary

WSA Boundary

Land Classification - Mineral Occurrence Map/Uranium   Big Pine GRA CA-08
Scale 1:250,000

N1-2B applies to all of WSA CA-010-063 except the part covered by N2-4D

N3-2B applies to all of WSA CA-010-059 except the part covered by N4-2D



EXPLANATION

△ Mine, commodity

○ Occurrence, commodity

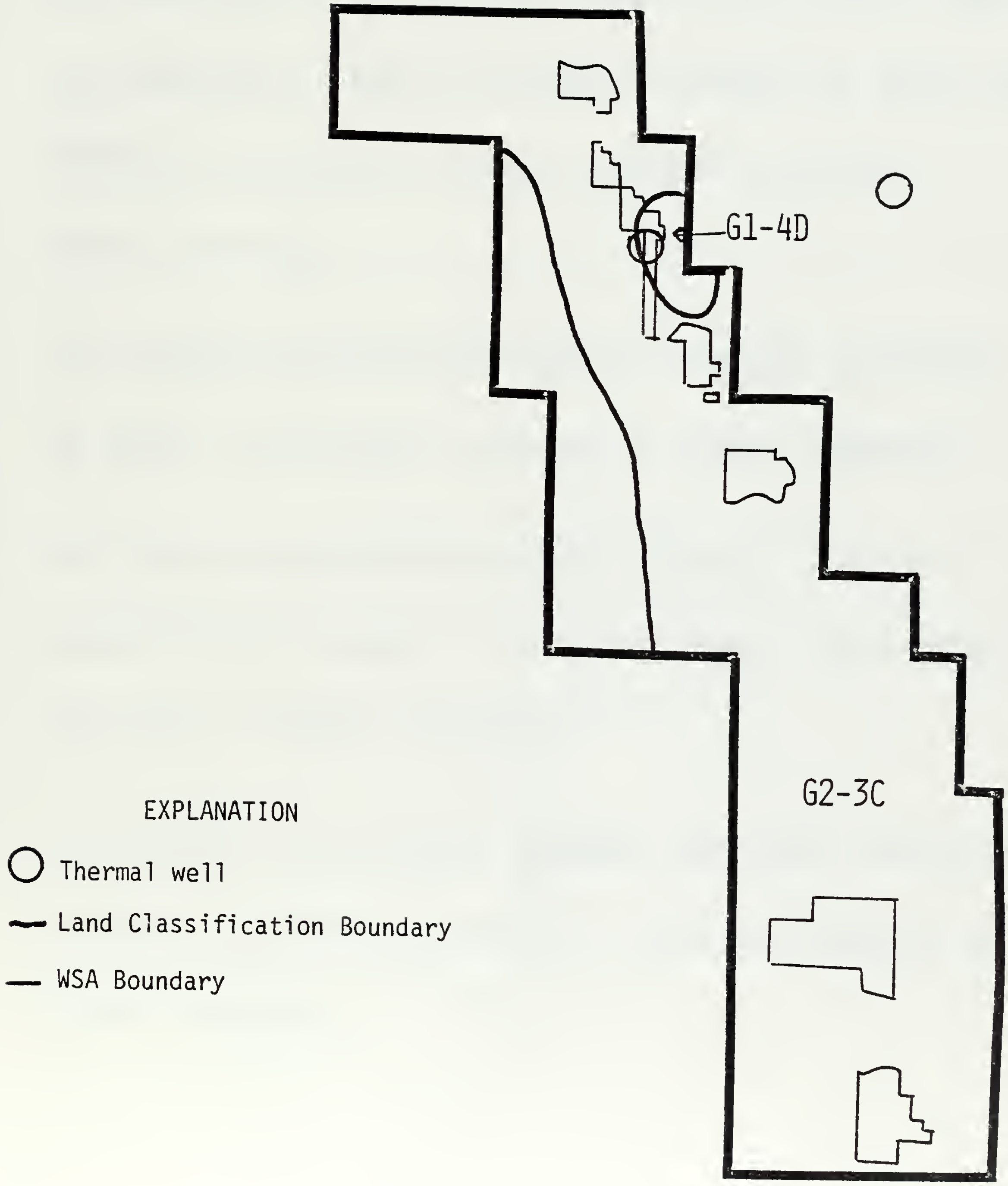
Land Classification Boundary

WSA Boundary

u - z WSA Segments

Land Classification - Mineral Occurrence Map/Nonmetallics

Big Pine GRA CA-08
Scale 1:250,000



Land Classification - Mineral Occurrence Map/Geothermal

Big Pine GRA CA-08
Scale 1:250,000

LEVEL OF CONFIDENCE SCHEME

A. THE AVAILABLE DATA ARE EITHER INSUFFICIENT AND/OR CANNOT BE CONSIDERED AS DIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES WITHIN THE RESPECTIVE AREA.

B. THE AVAILABLE DATA PROVIDE INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

C. THE AVAILABLE DATA PROVIDE DIRECT EVIDENCE, BUT ARE QUANTITATIVELY MINIMAL TO SUPPORT TO REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

D. THE AVAILABLE DATA PROVIDE ABUNDANT DIRECT AND INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

CLASSIFICATION SCHEME

1. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES DO NOT INDICATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

2. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES INDICATE LOW FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

3. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, AND THE REPORTED MINERAL OCCURRENCES INDICATE MODERATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

4. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, THE REPORTED MINERAL OCCURRENCES, AND THE KNOWN MINES OR DEPOSITS INDICATE HIGH FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE U.S. GEOLOGICAL SURVEY

Erathem or Era	System or Period		Series or Epoch	Estimated ages of time boundaries in millions of years
Cenozoic	Quaternary		Holocene	
			Pleistocene	2-3 [1]
	Tertiary		Pliocene	12 [1]
			Miocene	26 [2]
			Oligocene	37-38
			Eocene	53-54
			Paleocene	65
Mesozoic	Cretaceous [4]		Upper (Late) Lower (Early)	136
	Jurassic		Upper (Late) Middle (Middle) Lower (Early)	190-195
	Triassic		Upper (Late) Middle (Middle) Lower (Early)	225
Paleozoic	Permian [4]		Upper (Late) Lower (Early)	280
	Carboniferous Systems	Pennsylvanian [4]	Upper (Late) Middle (Middle) Lower (Early)	
		Mississippian [4]	Upper (Late) Lower (Early)	345
	Devonian		Upper (Late) Middle (Middle) Lower (Early)	395
	Silurian [4]		Upper (Late) Middle (Middle) Lower (Early)	430-440
	Ordovician [4]		Upper (Late) Middle (Middle) Lower (Early)	500
	Cambrian [4]		Upper (Late) Middle (Middle) Lower (Early)	570
Precambrian [3]			Informal subdivisions such as upper, middle, and lower, or upper and lower, or younger and older may be used locally.	3,600+ [3]

[1] Holmes, Arthur, 1965, Principles of physical geology: 2d ed., New York, Ronald Press, p. 360-361, for the Pleistocene and Pliocene; and Obradovich, J. D., 1965, Age of marine Pleistocene of California: Am. Assoc. Petroleum Geologists, v. 49, no. 7, p. 1087, for the Pleistocene of southern California.

[2] Geological Society of London, 1964, The Phanerozoic time-scale; a symposium: Geol. Soc. London, Quart. Jour., v. 120, supp., p. 260-262, for the Miocene through the Cambrian.

[3] Stern, T. W., written commun., 1968, for the Precambrian.

[4] Includes provincial series accepted for use in U.S. Geological Survey reports.

Terms designating time are in parentheses. Informal time terms early, middle, and late may be used for the eras, and for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms lower, middle, and upper may be used where there is no formal subdivision of a system or of a series.

GEOLOGIC NAMES COMMITTEE, 1970